Turkish Journal of Computer and Mathematics Education Vol.12 No.14(2021), 4589- 4599
Research Article

Exponential Model Versus Polynomial Model to Describe Height Growth of Balangeran *(Shorea balangeran)* Plant in Peat Swamp Lands

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Abstract

Balangeran tree has excellent economic benefits and ecological value because the wood has a high selling price. The purpose of this study was to create exponential and polynomial models to describe the height growth of balangeran planted on peat swamp lands in Central Kalimantan, Indonesia. Research result show that exponential equation is valid to describe the height growth of balangeran plants with an accuracy of 97.02% and a coefficient of determination of 78.86%; meanwhile, the polynomial equation is also valid to describe the height growth of balangeran plants with an accuracy of 99.76% and a coefficient of determination of 98.92%.
Keywords: balangeran, exponential, polynomial, growth.

1. Introduction

Balangeran (*Shorea balangeran* Korth. Burck) is a type of tree that grows naturally in peat swamp areas in Central Kalimantan, Indonesia. Balangeran tree has excellent economic benefits and ecological value because the wood has a high selling price (Martawijaya et al., 1989; Setyo et al., 2012), and has a major role in maintaining the sustainability of the peat swamp forest ecosystem (Rachmanadi, 2012).

Balangeran trees are currently in the critical category (critically endangered) according to the International Union for Conservation of Nature (IUCN), namely the conservation status given to species that face the risk of extinction in the near future, caused by forest and land fires, illegal logging and land conversion (Darwo and Bugidarmanti, 2013). Thus, planting efforts are needed to conserve this species while rehabilitating degraded peat swamp lands in Central Kalimantan.

Efforts to conserve the balangeran species that have been carried out by making balangeran seedlings, land preparation and planting the balangeran species on peat swamp lands. Another effort is to create a growth model for balangeran plants in peat swamp lands. The growth modeling of balangeran plants in peat swamp land aims to describe the growth patterns of these plants in peat swamp lands. The purpose of this study was to create exponential and polynomial models to describe the height growth of balangeran planted on peat swamp lands in Central Kalimantan, Indonesia.

2. Research Methodology

2.1. Place of research

The research was conducted in the balangeran planting area at the peat swamp land in Pulang Pisau Regency, Central Kalimantan Province. The samples of this research were balangeran plants planted on peat swamp lands at age classes 1, 2, 5, 6, 8, 9, 12 and 15 years, each with 200 plants. So that overall this study uses a sample of 1,600 (= 8x200) balangeran plants.

2.2. Plant growth models

a. The exponential equation model is used to make a height growth model for balangeran (Brown, 1997; Grant et al., 1997; Radonsa et al., 2003; Wahyudi, 2015), namely:

$y = c1.e^{c2X}$
where: x = initial diameter
y = final diameter
c1, c2 = constant
e = 2,7183

b. The polynomial equation model is also used to make a height growth model for balangeran (Brown, 1997; Burckhart, 2003; Wahyudi, 2015), namely:

$y = c_1 + c_2x + c_3x^2$
where: x = initial diameter
y = final diameter
c1, c2 = constant
e = 2,7183

2.3. Validation and accuracy of plant growth models

a. Validation of the height growth model for balangeran plants was carried out using the Chi Squared formula (Sudjana, 2021) as follows:

$$\chi^2 = \sum_{i=1}^{n} \frac{(O_i - E_i)^2}{E_i}$$

Where:
$\chi 2$ = Chi square
Oi = actual data /observed data to-i
Ei = expected data / data from the model to-i
N = number of data
Criteria:
If the value of χ^2 count $\geq \chi^2_{\text{table (db-1; 0.05)}}$, then accept H1
If the value of χ^2 count $< \chi^2_{\text{table (db-1; 0.05)}}$, then accept H0

b. The accuracy of the height growth model for balangeran plants is calculated based on the Mean Absolute Percentage Error (MAPE) with the following equation (Wahyudi, 2015):

$$y = 100\% - [1/n \sum_{i=1}^{n} \frac{|O_i - E_i|}{E_i} x\ 100\%]$$

where:
y = Accuracy of the model
Oi = actual data /observed data to-i
Ei = expected data / data from the model to-i
N = number of data
Criteria:
Y > 80% = very accurate
y = 75% - 79.99% = accurate
y = 60% - 74.99% = quite accurate
y < 60% = inaccurate.

c. The coefficient of determination (R^2) shows the level of correlation between the independent variables and the dependent variable.
Criteria:
R^2 > 80% = highly correlated
R^2 = 75% - 79.99% = correlated
R^2 = 60% - 74.99% = sufficiently correlated
R^2 < 60% = uncorrelated.

2.4. Data processing and devices

The height data of balangeran plants in age classes 1, 2, 5, 6, 8, 9, 12 and 15 years were then calculated the average, a growth model was made based on the time function (years) using exponential and polynomial equations. The growth model is then tested for validity, accuracy and the level of correlation between the independent variables and dependent variables.

Based on the results of these tests, the best balangeran plant height growth equation model was chosen, namely a model that is valid, accurate and has a high coefficient of determination. The best model is suggested to be used in predicting the height growth of balangeran planted in peat swamp land. Data processing was performed using Microsoft Excel software.

3. Results and Discussion

3.1. Balangeran plant height data

The height measurement of balangeran plants planted on peat swamp lands in Central Kalimantan was carried out on balangeran plants with age classes 1, 2, 5, 6, 8, 9, 12 and 15 years, each composed of 200 plant samples. The average measurement data is shown in Table 1.

Table 1. Average data on height of balangeran

No	1	2	3	4	5	6	7	8
Plant Age (Years)	1	2	5	6	8	9	12	15
Average Plant Height (m) *	0.61	1.21	5.01	6.42	9.44	10.64	12.67	13.69

*each compiled from 200 balangeran plant data
Source: Data processed in 2021

3.2. Plant height growth modeling

Balangeran plant height growth data modeling used exponential and polynomial equations as well as validation, accuracy and correlation test results.

3.2.1. Exponential equation model

The exponential equation is created using Microsoft Excel software as follows:

a. Open Microsoft Excel
b. Open data on height growth for age classes 1, 2, 5, 6, 8, 9, 12 and 15 years
c. Click: Insert
d. Click: Scatter → Scatter with only markers
e. Click: Select Data → High growth data blocks for age classes 1, 2, 5, 6, 8, 9, 12 and 15 years)
f. Click: Add trendline
g. Click: exponential → Click: Display Equation on chart
→ Click: Display R-Squared value on chart
h. Complete the graphic display via Chart layouts →Fig.1

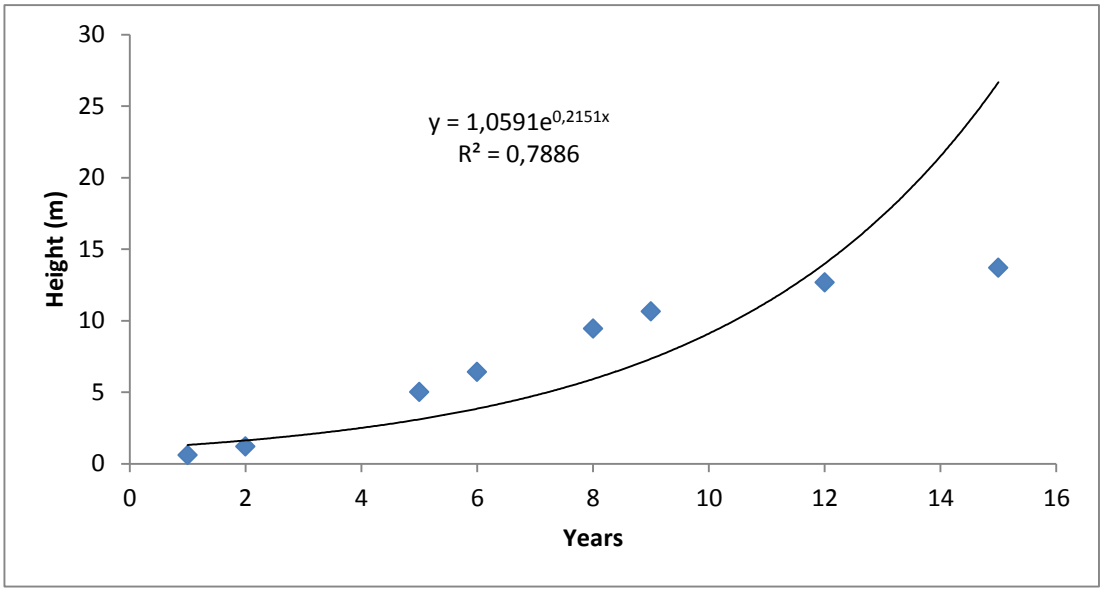

Fig.1. Exponential model to describe the height growth of the balalangeran plant

Based on Figure 1, it can be seen that the exponential equation to describe the height growth of Balangeran plants is as follows:

$y = 1.0591.e^{0.2151x}$
where:
x = initial diameter
y = final diameter

This equation has a good determination coefficient with R^2 value of 78.86%. This shows that the relationship between the independent variable (X) and the dependent variable (Y) is good so that the equation can be used to describe the height growth of balangeran plants based on the function of time (years). With this exponential equation, farmers or planters of balangeran plants can predict the height of balangeran plants at a certain age, so that they can get an overview of the crop yields and make predictions of the feasibility of balangeran plant business in peat swamp land.

3.2.2. Polynomial equation model

The exponential equation is created using Microsoft Excel software as follows:

a. Open Microsoft Excel
b. Open data on height growth for age classes 1, 2, 5, 6, 8, 9, 12 and 15 years
c. Click: Insert
d. Click: Scatter → Scatter with only markers
e. Click: Select Data → High growth data blocks for age classes 1, 2, 5, 6, 8, 9, 12 and 15 years)
f. Click: Add trendline
g. Click: polynomial →Click: Display Equation on chart
Click: Display R-Squared value on chart
h. Complete the graphic display through Chart layouts → Show Fig.2

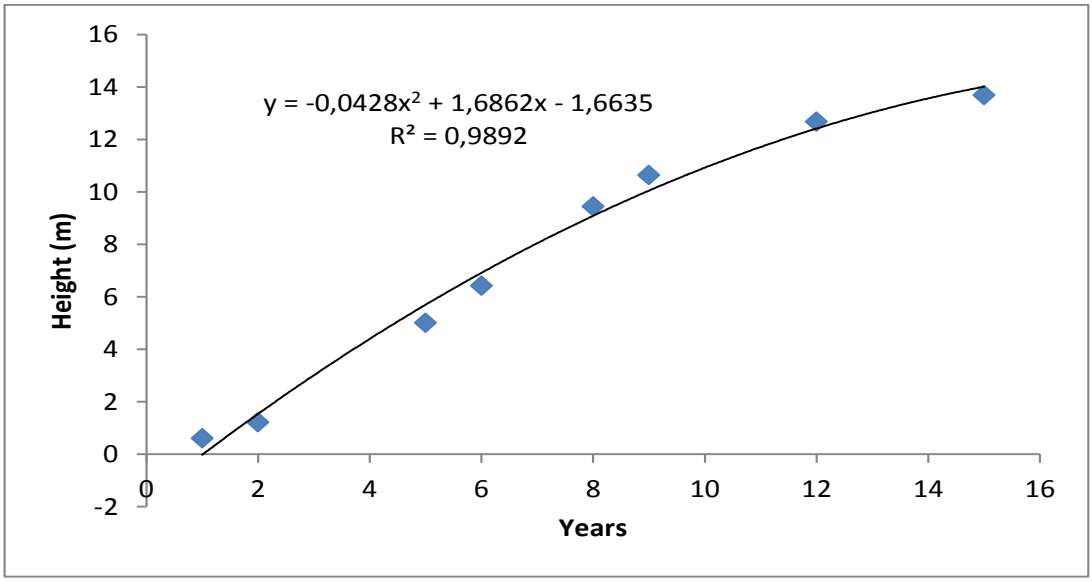

Fig.2. Polynomial model to describe the height growth of the balalangeran plant

Figure 2, shows a graph of the height growth of balangeran plants is shown using the polynomial model. Based on the graph, it can be seen that the polynomial equation to describe the height growth of the balangeran plant is as follows:

$y = -1.6635 + 1.686\ x - 0.0428\ x^2$
where:
x = initial diameter
y = final diameter

The resulting polynomial equation has very good determination coefficient with R^2 value of 98.92%. This shows that the relationship between the independent variable (X) and the dependent variable (Y) is very good so that the equation can be used to describe the height growth of balangeran plants based on the function of time (years). With this polynomial equation, farmers or businessmen of balangeran plants can predict the height of balangeran plants at a certain age, so that they can get an overview of the crop yields and make predictions of the feasibility of balangeran plant business on peat swamp

3.3. Model validation

Model validation is testing the validity of the model by comparing the actual (observed) data with the expected data. Model validation can use the Chi Square standard ($\chi 2$) (Sudjana, 2021). The results of the Chi square calculation are presented in Table 2.

Table 2. Calculations for the exponential and polynomial equation model validation

Year	O	Ee	O-Ee	$(O-Ee)^2/Ee$	Ep	O-Ep	$(O-Ep)^2/Ep$
1	0.61	0.801	-0.19	0.045	-0.651	1.261	-2.443
2	1.21	1.589	-0.38	0.090	0.314	0.896	2.555
5	5.01	6.759	-1.57	0.374	5.710	-0.700	0.086
6	6.42	8.431	-2.01	0.479	7.397	-0.978	0.129
8	9.44	12.397	-2.96	0.705	10.440	-1.000	0.096
9	10.64	13.973	-3.33	0.795	11.432	-0.792	0.055
12	12.67	16.639	-3.97	0.946	12.830	-0.160	0.002
15	13.69	17.978	-4.29	1.023	13.399	0.291	0.006
	Total	78.389	-18.699	4.460	60.873	-1.183	0.006

Where:
O : Observed, namely the average of the observed data or measurement data
Ee : Expected exponential, namely the data expected from the equation model exponential
Ep : Expected polynomial, namely the expected data from the equation model polynomial

3.3.1. Exponential model validation

Based on Table 2, the exponential model validation at the 99% confidence level and corrected degrees of freedom (db-1): 7 → obtained table values $\chi^2_{0.01}$: 18.5.

Meanwhile, the count value of χ^2 for the exponential equation is (O-Ee) ^{2} / Ee = 4.46 → Then:
a. The count value of χ^2 (= 4.46) < table value of $\chi^2_{0.01}$ (= 18.5)
b. Accepted: H0
c. Observed data and expected data do not differ significantly at the 99% level
d. Validation conclusion: The exponential equation model is valid.

3.3.2. Polynomial model validation

Based on Table 2, the polynomial model validation at the 99% confidence level and corrected degrees of freedom (db-1): 7 → obtained table values $\chi^2_{0.01}$: 18.5. Meanwhile, the count value of χ^2 for the exponential equation is (O-Ee) ^{2} / Ee = 0.006 → Then:
a. The count value of χ^2 (= 0.006) < table value of $\chi^2_{0.01}$ (= 18.5)
b. Accepted: H0
c. Observed data and expected data do not differ significantly at the 99% level
d. Validation conclusion: The polynomial equation model is valid.

3.4. Model accuracy

Model accuracy is the level of accuracy of an equation model that is shown through the percentage or Mean Absolute Percentage Error (MAPE) (Wahyudi, 2015). The higher the percentage, so the more accurate the equation will be.

3.4.1. Exponential model accuracy

Based on Table 2, the MAPE value of the exponential equation can be calculated as follows:

$$\text{MAPE} = [1/8 \frac{|-18.699|}{78.389} \text{ x } 100\%] = 2.9817\ \%$$

So the level of accuracy of the exponential equation model is 100% - 2.9817% = 97.02%

3.4.2. Polynomial model accuracy

Based on Table 2, the MAPE value of the polynomial equation can be calculated as follows:

$$\text{MAPE} = [1/8 \frac{|-1.183|}{60.873} \text{ x } 100\%] = 0.2429\ \%$$

So the level of accuracy of the exponential equation model is 100% - 0.2429% = 99.76%.

4. Conclusion

Exponential equation is valid to describe the height growth of balangeran plants with an accuracy of 97.02% and a coefficient of determination of 78.86%; meanwhile, the polynomial equation is also valid to describe the height growth of balangeran plants with an accuracy of 99.76% and a coefficient of determination of 98.92%.

6. Suggestions

It is necessary to conduct research to obtain a growth model for the diameter and volum of balangeran plants in peat swamp land.

7. Acknowledgments

Thank you to the head of the Central Kalimantan Provincial Forestry Service, the head of Pulang Pisau Districk, the head of the Forestry Research Institute of Tumbang Nusa, and friends who supported this research.

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